



# Ground-validation of DPR precipitation rate over Italy

PMM Science meeting, 24-28 October 2016, Houston, TX,

**Silvia Puca<sup>1</sup>, Marco Petracca<sup>1,2</sup>, Gianfranco Vulpiani<sup>1</sup>  
Leo Pio D'Adderio<sup>2</sup>, Martina Buiat<sup>2</sup>, Federico Porcù<sup>3</sup>**

- 1) *National Civil Protection Department, Rome, Italy.*
- 2) *Dept. of Physics and Earth Science, University of Ferrara, Italy.*
- 3) *Dept. of Physics and Astronomy, University of Bologna, Italy.*



## Outlines

- The H-SAF validation strategy
- The Italian ground-reference network
- Performance analysis
- Summary
- Next steps





A Proposal to NASA's Global Precipitation Mission

## H-SAF and GPM: precipitation algorithm development and validation activity

### Principal Investigators:

Giulia Panegrossi (ISAC/CNR; PP Algorithm Development):

Main contact person

Scientific Coordinator of the algorithm development activity

Silvia Puca (DPC; H-SAF Project Team member – PP Validation)

Scientific Coordinator of the validation activity

Paolo Rosci (ITAF-USAM; H-SAF Scientific Management)

H-SAF-GPM Management coordinator

### Co-PI's:

Vincenzo Levizzani (ISAC/CNR): (JPWG coordinator and H-SAF Project Team member)

Stefano Dietrich (ISAC/CNR): (H-SAF Project Team member – PP Algorithm Development)

Francesco Zauli (ITAF-CNMCA) (H-SAF Leader of precipitation cluster)

Federico Porcù (University of Ferrara)

Gianfranco Vulpiani (DPC)

### Co-Investigators:

Daniele Casella, Elsa Cattani, Sante Laviola, Paolo Sanò (ISAC-CNR)

Angelo Rinollo (DPC)

Davide Melfi, Massimiliano Sist (ITAF-CNMCA)

Vinia Mattioli (H-SAF visiting scientist)

# Proposal promoting collaboration between H-SAF and GPM

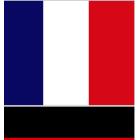
- The goal is to contribute toward the establishment of a long term collaboration between EUMETSAT H-SAF and GPM on the following aspects:
  - precipitation retrieval algorithm development**, through a fruitful interaction on several critical aspects of interest both to H-SAF and GPM (**ISAC-CNR, CNMCA**); **Scientific coordinator: Giulia Panegrossi**

**validation activity**, through the connection between the well established H-SAF product validation (**DPC, IMGW, and PPVG**) and hydrological validation (**IMGW**) programs and the Ground Validation/Calibration activity of GPM;  
**Scientific Coordinator: Silvia Puca**

- Active participation of H-SAF to GPM EM phase:**
  - Daily download of “Europe” subset of GPM products
  - Analysis of case studies and extensive validation over Europe of GPM products;
  - H-SAF validation of GMI product during 2014;
  - H-SAF validation of DPR products.**

# EUMETSAT SAF on Support to Operational Hydrology and Water Management

<http://hsaf.meteoam.it>



## Objectives:

1) To provide **operational** high quality level 2/3 products and develop **new products** from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology;

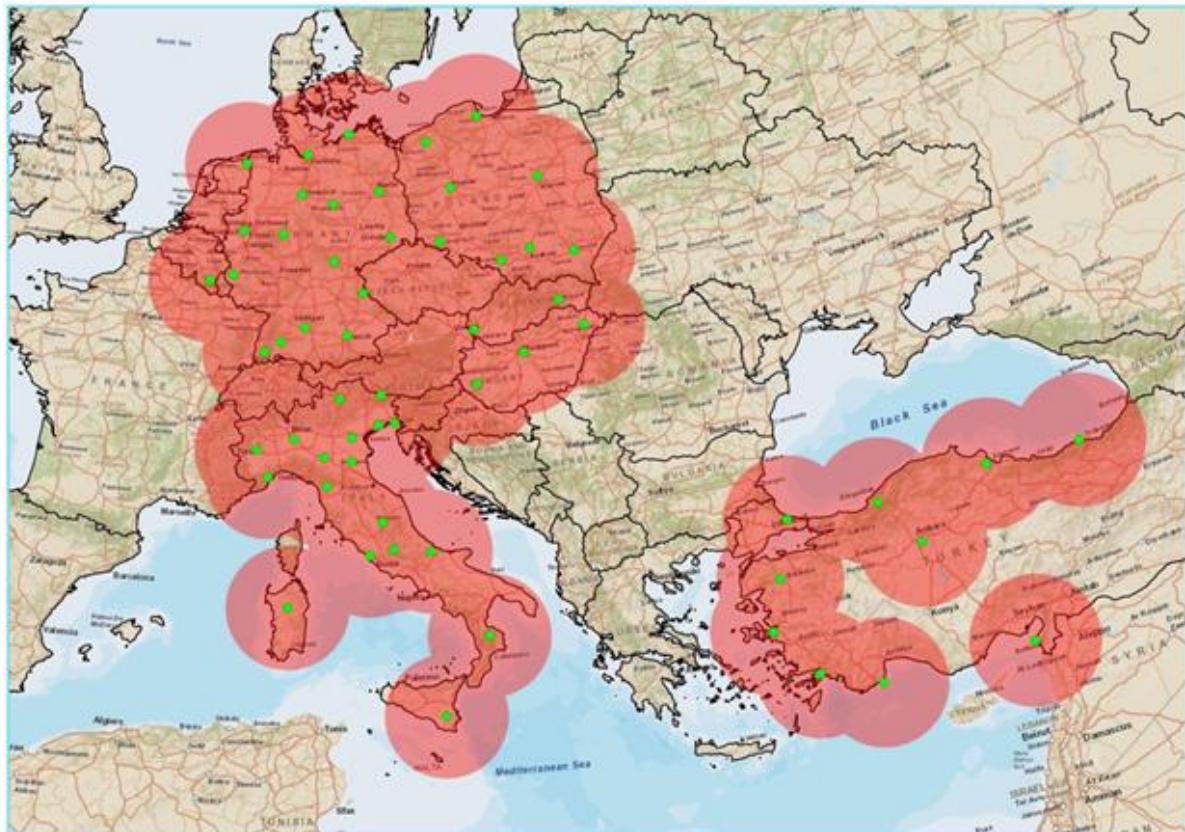
- **precipitation** (liquid, solid, rate, accumulated); Leader, Italy (**ISAC-CNR, CNMCA**);
- **soil moisture** (at large-scale, at local-scale, at surface and in roots region); Leader Austria (**TU-Wien**);
- **snow parameters** (detection, cover, melting conditions, water equivalent); Leader Finland, Turkey)

To provide **independent validation** to verify the usefulness of the products for civil protection purposes (floods, landslides, etc..), and for monitoring water resources, and the impact in hydrological models.

# H-SAF Precipitation Product Validation Group

All the ground data used in H-SAF PPVG has a **QUALITY INDEX** associated

The quality indexes (rain gauges and radar) are evaluated following the same methodology in each countries



## 54 C-band radar

All radars have Doppler capability, however, not all of them have dual polarization.

- All radars available to PPVG are regularly maintained and calibrated.
- Each country has its own processing chain to estimate the Surface Rainfall Intensity

PPVG has defined a common methodology to evaluate the quality index directly from the radar raw data available in the different countries, in order to unify precipitation field and quality index generation

# Common Validation Strategy

Main task:

- Provide error structure information to the users for operational applications:
  - Nowcasting;
  - Assimilation in the hydrological model;

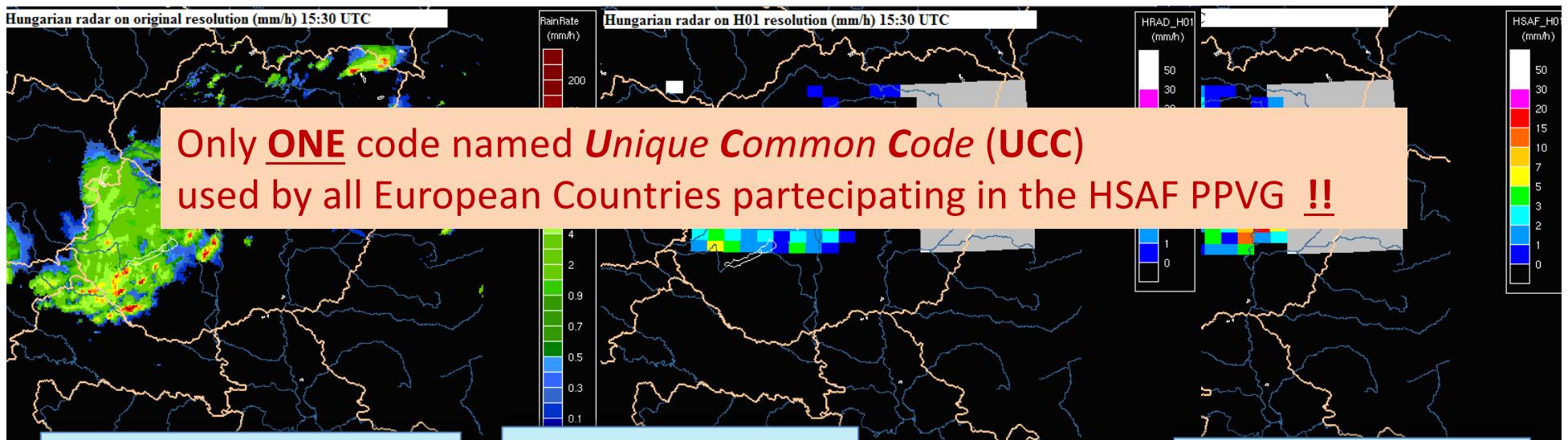
In order to **make comparable the statistical results obtained by several institutes** and to better understand their meanings it has been necessary define a **COMMON VALIDATION METHODOLOGY (ground quality estimation, statistical scores evaluation)**

The **common** validation methodology is based on ground data (radar and rain gauges) comparisons **on SATELLITE NATIVE GRID** to produce

- **large statistic** (continuous and multi categorical) on **one or more years of data**
- and **case study analysis**.



Muti –categorical and continuous statistical scores are evaluated



Only ONE code named ***Unique Common Code (UCC)*** used by all European Countries partecipating in the HSAF PPVG !!

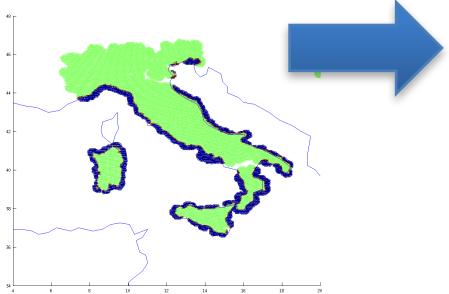
SEA, LAND, COAST mask

Statistical scores

Precip. classes

#### CS statistic:

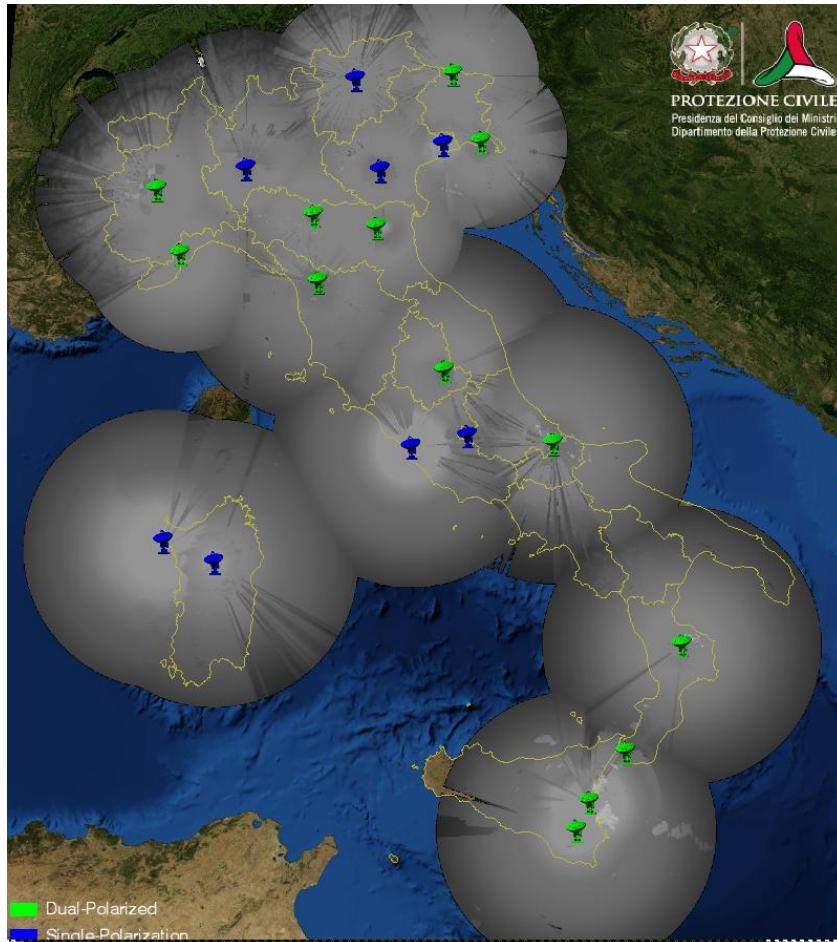
- Number of points
- observed Mean rain
- Satellite Mean
- Observed Max
- Satellite Max
- Mean error
- Multiplicative bias
- Mean absolute error
- Root mean square error
- correlation coefficient
- Standard deviation



CLASS	RAIN RATE (RR) PRODUCTS
Class 1	0.25mm/h <= RR
Class 2	1 mm/h < = RR
Class 3	10 mm/h <= RR

# Italian RADAR network

DATA: RADAR



- Federated network
- **21** radar systems managed by **11** administrations
- DPC is responsible for the generation and dissemination of products at national level
- Radar DPC: 6 C-band + 2 X-band, all with dual-pol capability
- About 65% of the network is composed by polarimetric systems (11 at C-band and 2 at X-band).
- With the new radars in Sardinia the percentage should increase up to 75%

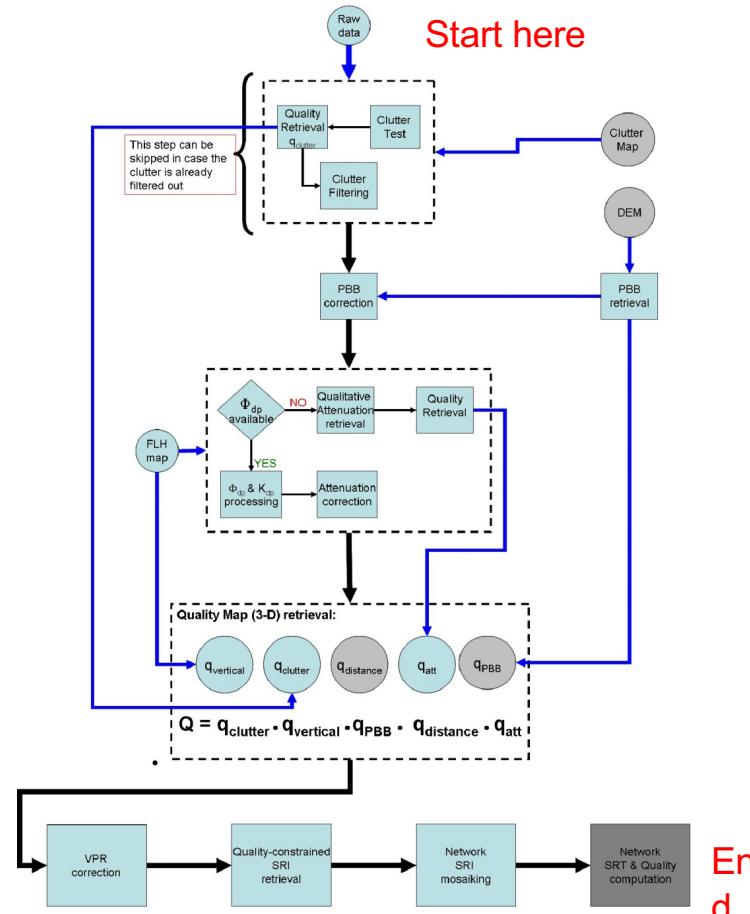


# Applied data processing chain with embedded data quality scheme

DATA: RADAR

**The quality is used to:**

- a) filter out non-weather returns (Vulpiani et al., 2012)
- b) combine the entire radar volume (through a weighted combination) to obtain the single radar rainfall map (Tabary et al., 2007)
- c) combine single-radar rainfall maps to construct the national composite (Vulpiani et al., 2014)

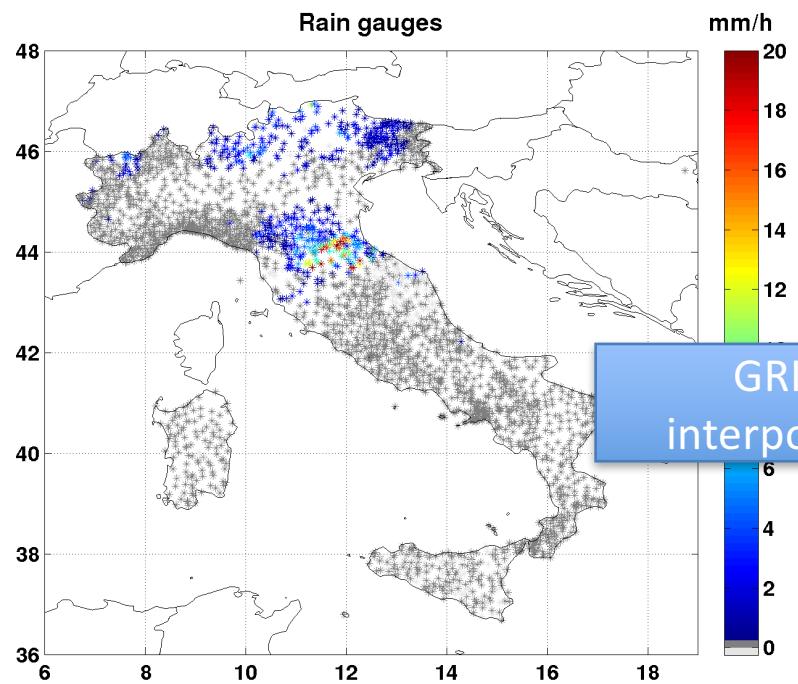


# Italian rain gauges network

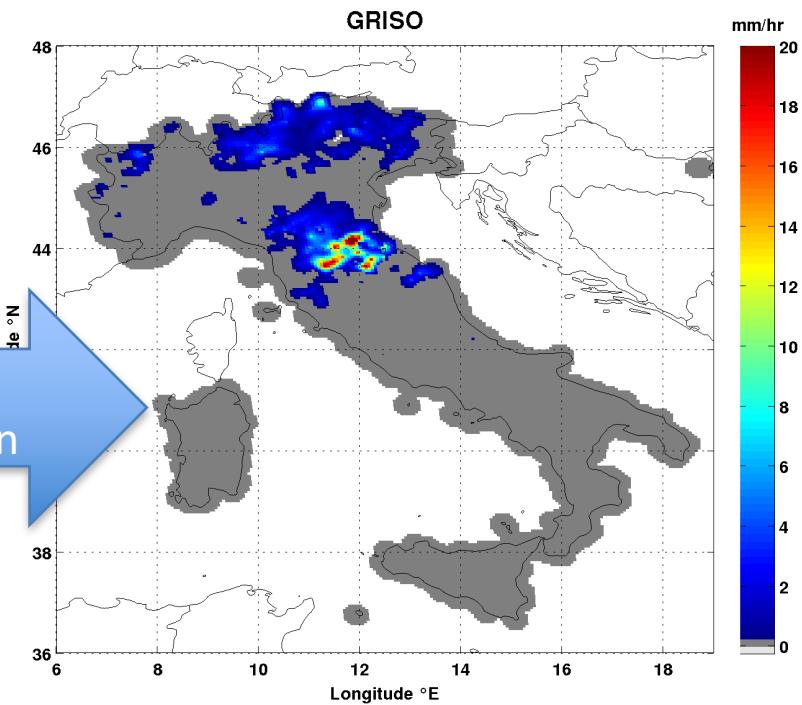
DATA: RAIN GAUGE

[www.protezionecivile.gov.it](http://www.protezionecivile.gov.it)

The Italian national pluviometric network consists of more than 2500 Tipping Bucket raingauges, providing cumulated precipitation every 30 or 60 minutes, with a step of 0.1 or 0.2mm.



GRISO  
interpolation



# DPR validation

**DATA: GPM**

[www.protezionecivile.gov.it](http://www.protezionecivile.gov.it)

- Product Level 2A DPR V04 HDF5

PrecipRateESurface, PrecipRateNearSurface

LandSurfaceType, PhaseNearSurface

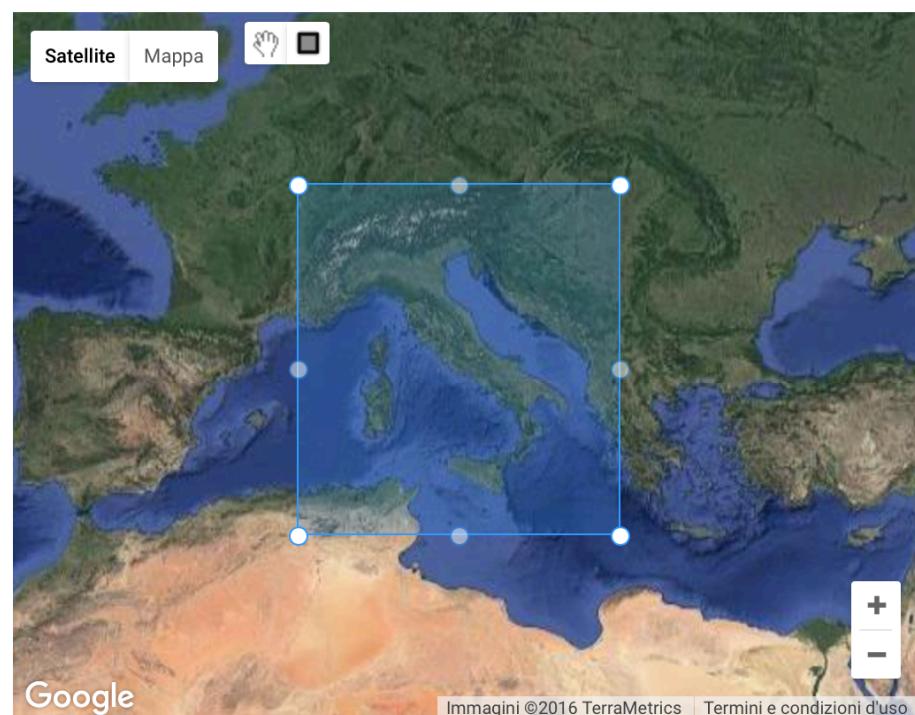
for all scansions: **NS, MS and HS**

- Geographical subset over Italy:  
[35 - 48] ° N ; [5 - 21] ° E
- Period: 2014/03 – 2016/05 (27 months)
- Filters:
  - Land Surface
  - Liquid Phase Precipitation

*Use the buttons on the top-left to select a geographic area*

Lat Lng:

Place mouse over  to view the name of a Ground Validation Site.



Northern Latitude

Eastern Longitude

Southern Latitude

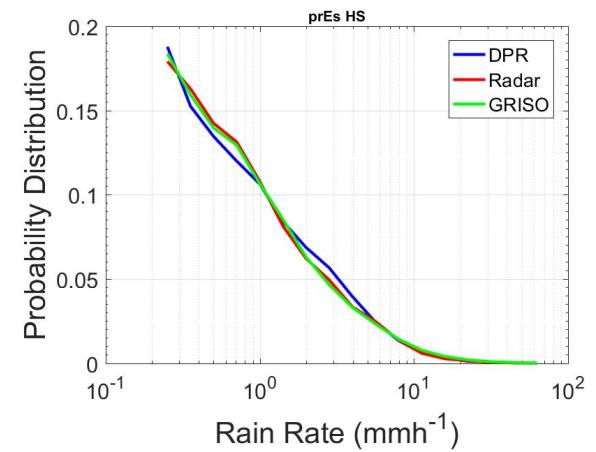
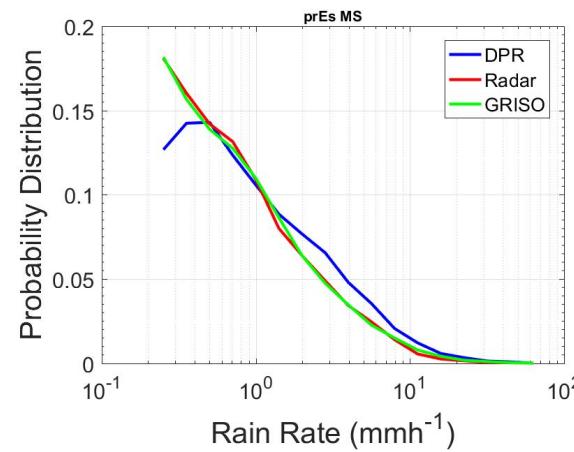
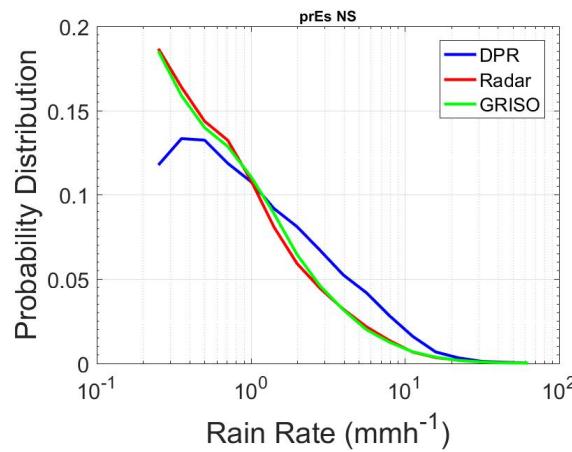
Western Longitude

# Statistical results

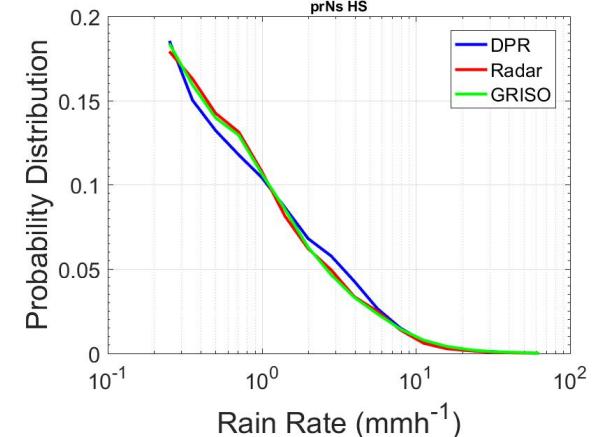
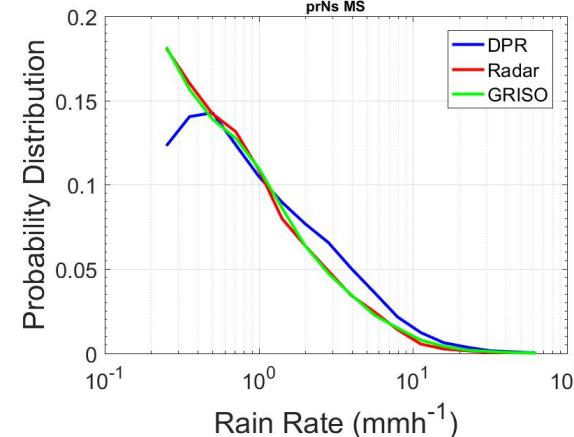
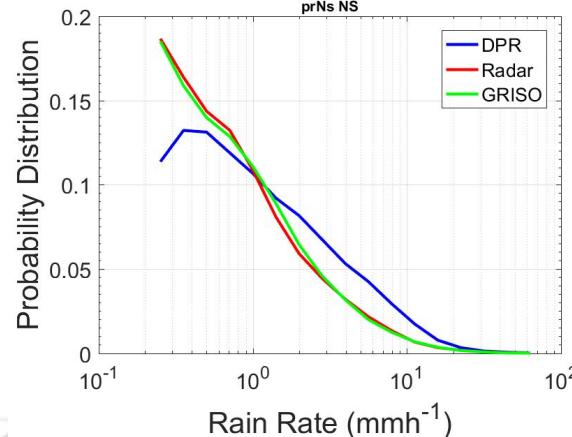
Results: PDF

Ground > 0.25 mm/h

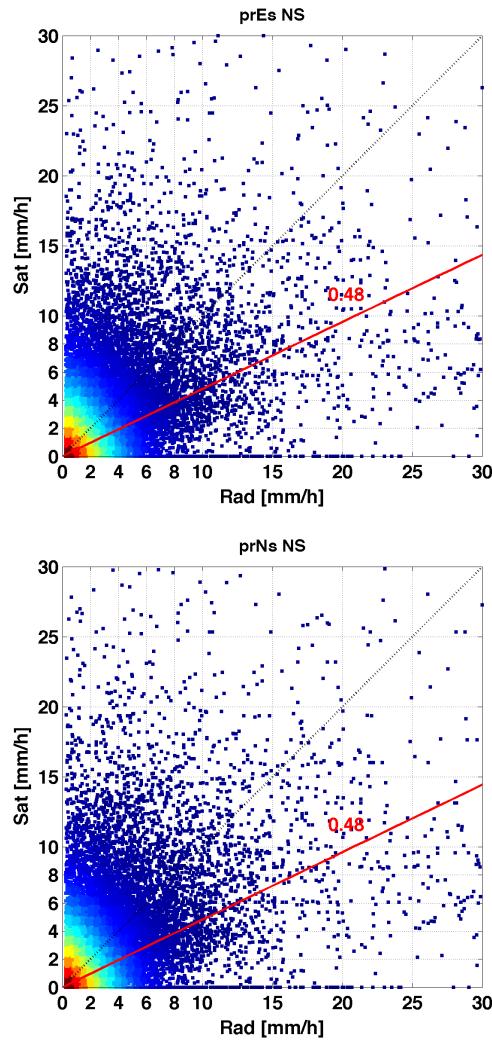
PrecipRateESurface



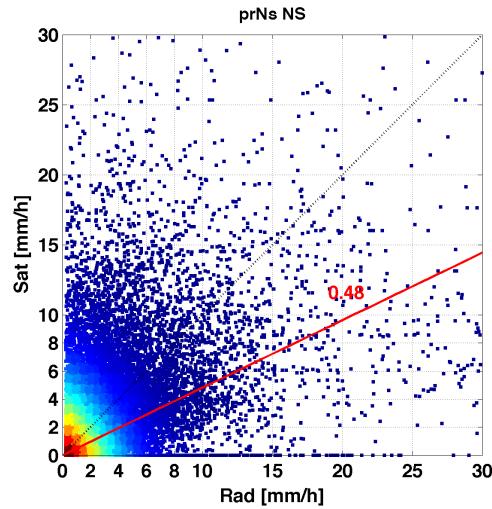
PrecipRateNearSurface



PrecipRateSurface



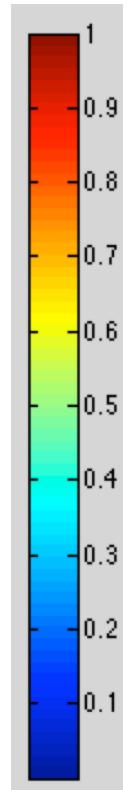
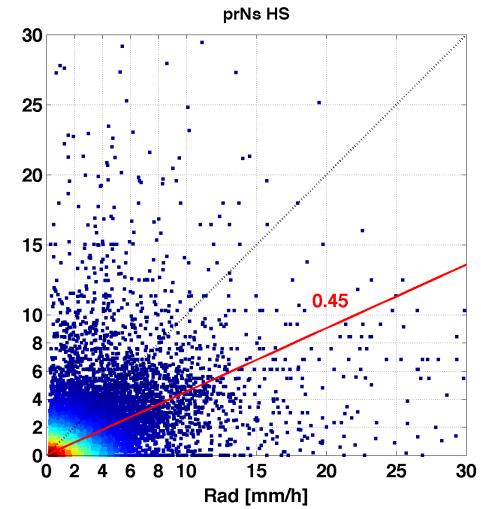
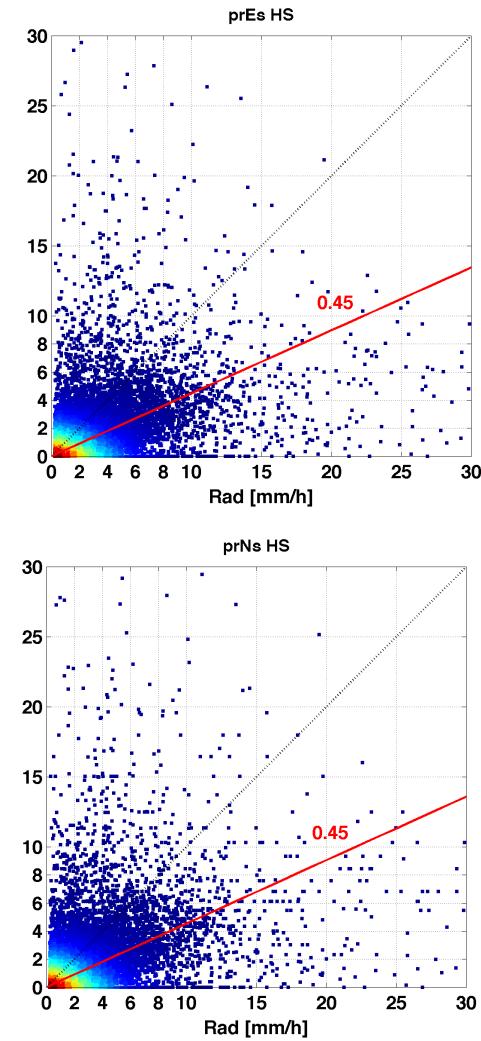
PrecipRateNearSurface



# RADAR

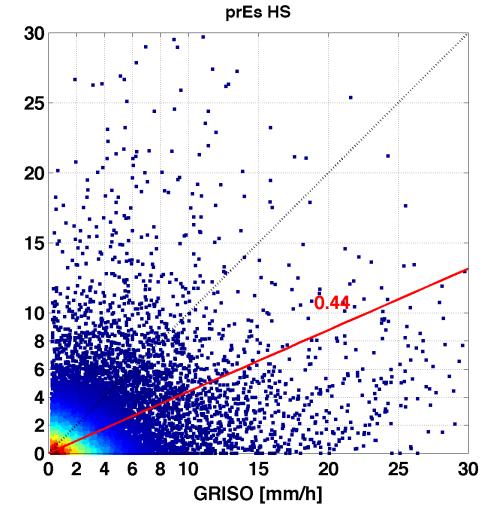
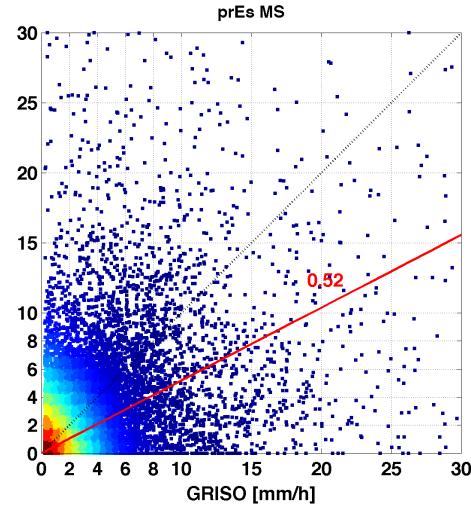
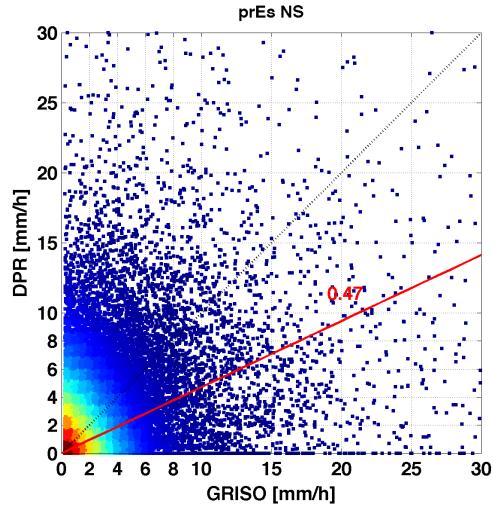
## Results: SCATTER

Ground > 0.25 mm/h

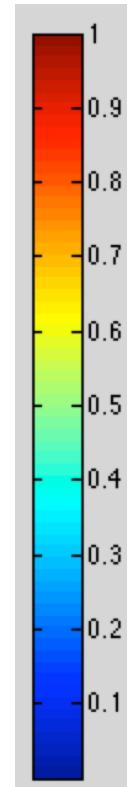
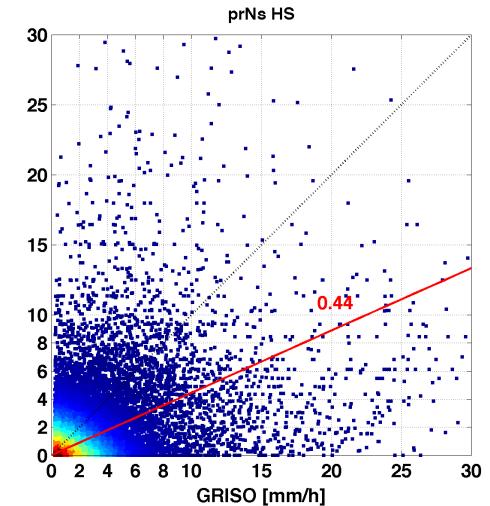
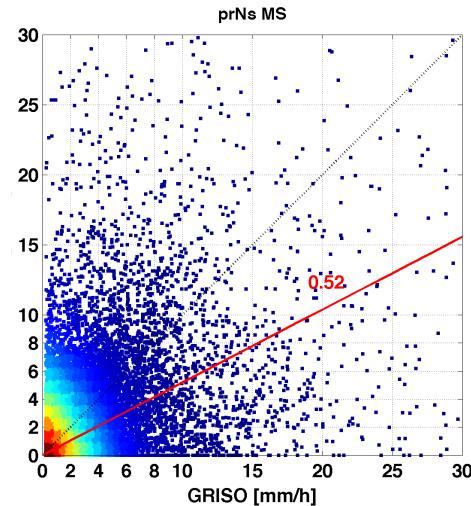
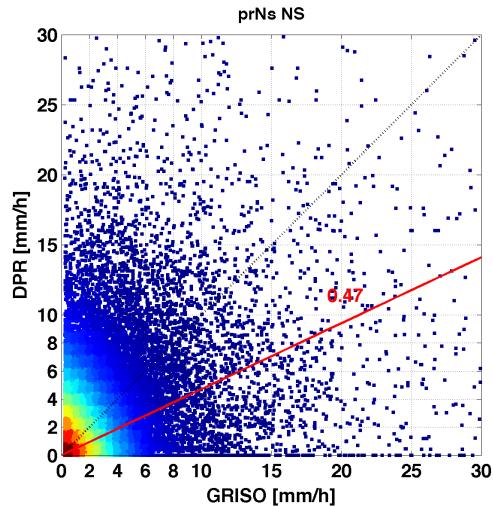


# GRISO

PrecipRateSurface



PrecipRateNearSurface



## Results: SCATTER

Ground > 0.25 mm/h

# Contingency tables

The percentages shown in a given column are computed with respect to the total number of satellite samples and represent how the satellite product classifies the events assigned to that class by the radar/rain gauges.

		NS					MS					HS					
		radar					radar					radar					
		mm/h	[0 - 0,25[	[0,25 - 1[	[1 - 10[	>=10	TOT	[0 - 0,25[	[0,25 - 1[	[1 - 10[	>=10	TOT	[0 - 0,25[	[0,25 - 1[	[1 - 10[	>=10	TOT
prNs	SAT	[0 - 0,25[	99,3%	65,9%	27,5%	8,5%	96,1%	99,2%	60,8%	23,3%	6,1%	95,7%	99,4%	66,5%	25,5%	6,3%	96,2%
		[0,25 - 1[	0,5%	23,2%	19,6%	1,9%	1,8%	0,6%	27,9%	22,4%	2,9%	2,2%	0,5%	26,5%	26,0%	5,9%	2,1%
		[1 - 10[	0,2%	10,6%	49,2%	55,4%	1,9%	0,2%	11,0%	51,4%	57,2%	2,0%	0,1%	6,8%	46,8%	76,5%	1,6%
		>=10	0,0%	0,3%	3,8%	34,2%	0,2%	0,0%	0,3%	2,9%	33,8%	0,1%	0,0%	0,1%	1,7%	11,4%	0,1%
		TOT	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
prEs	SAT	[0 - 0,25[	99,3%	66,3%	27,7%	8,5%	96,2%	99,2%	61,2%	23,5%	6,1%	95,7%	99,4%	68,3%	26,5%	6,5%	96,4%
		[0,25 - 1[	0,5%	23,2%	20,0%	1,9%	1,8%	0,6%	27,9%	22,9%	2,9%	2,2%	0,5%	25,6%	27,4%	6,5%	2,1%
		[1 - 10[	0,2%	10,2%	48,9%	58,2%	1,9%	0,2%	10,7%	51,0%	58,2%	2,0%	0,1%	6,0%	44,7%	78,7%	1,5%
		>=10	0,0%	0,3%	3,3%	31,4%	0,1%	0,0%	0,3%	2,7%	32,9%	0,1%	0,0%	0,1%	1,4%	8,4%	0,0%
		TOT	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

•The DPR has a good capability to discriminate rain-no rain precipitation.

The **NearSurface** and **EstimatedSurface** have really similar performances;

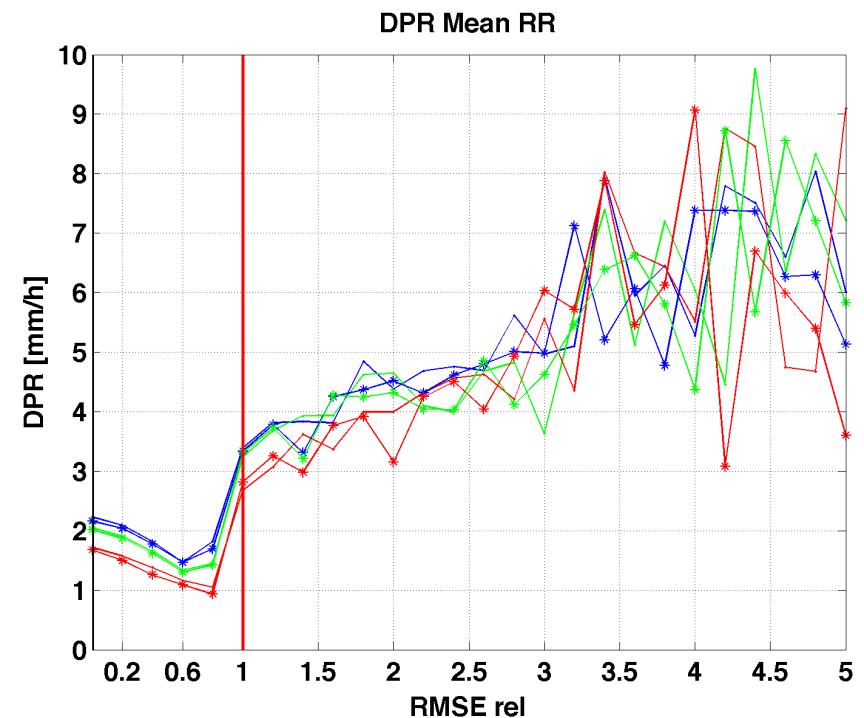
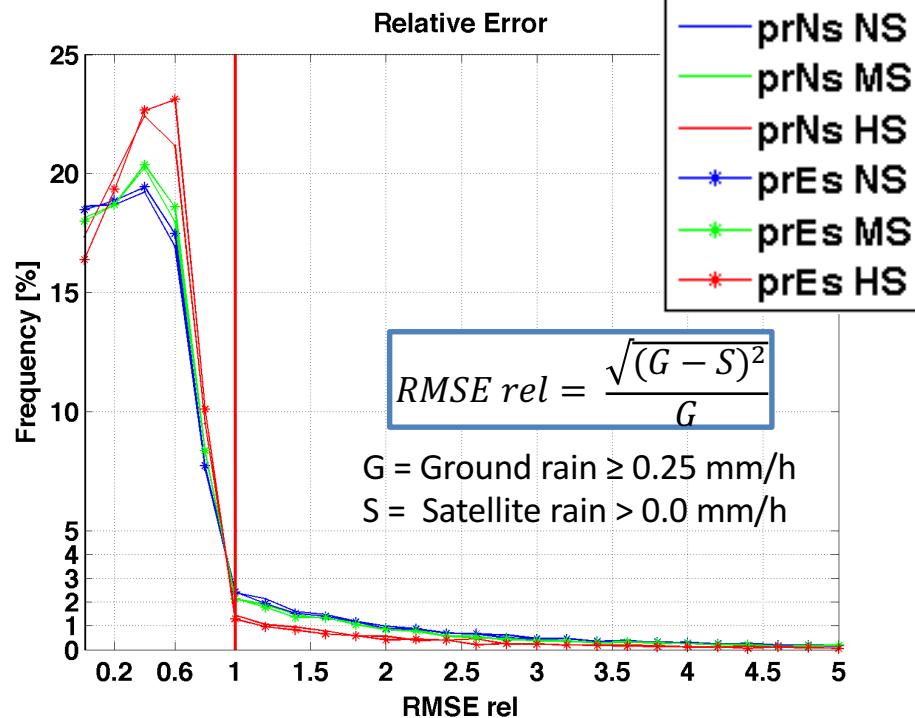
There is a general tendency of the PDR to underestimate the ground rain. Precipitation higher than 10 mm/h has been not observed by HS.



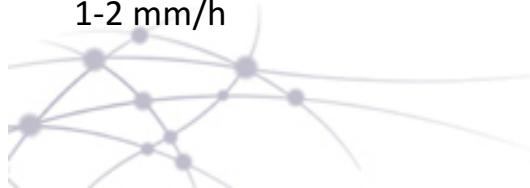
# RADAR

## Results: RMSE rel

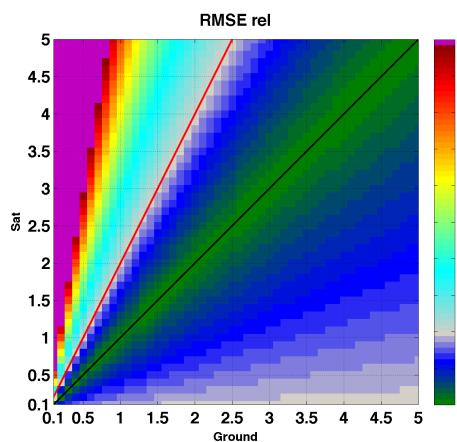
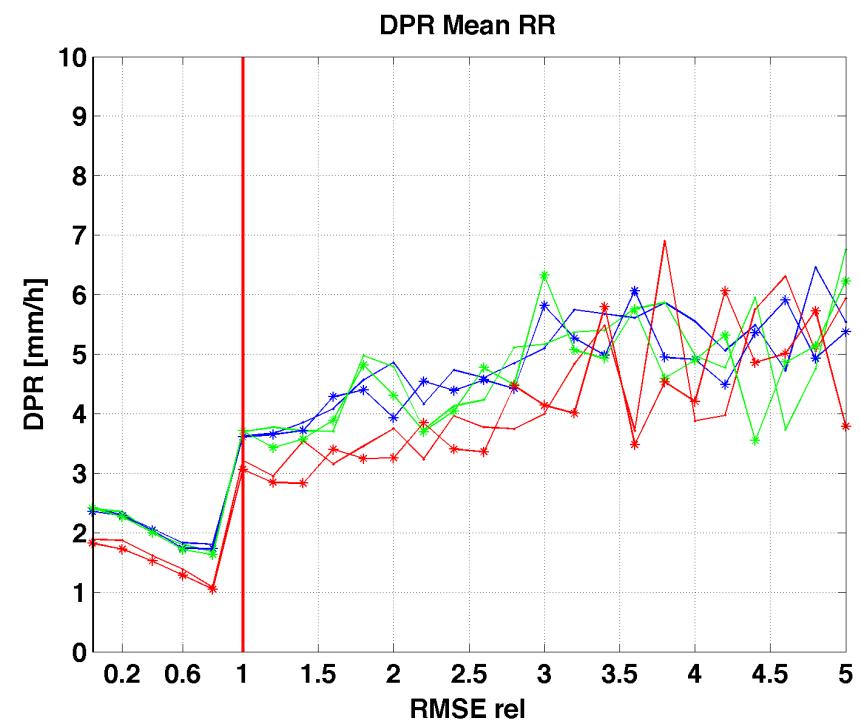
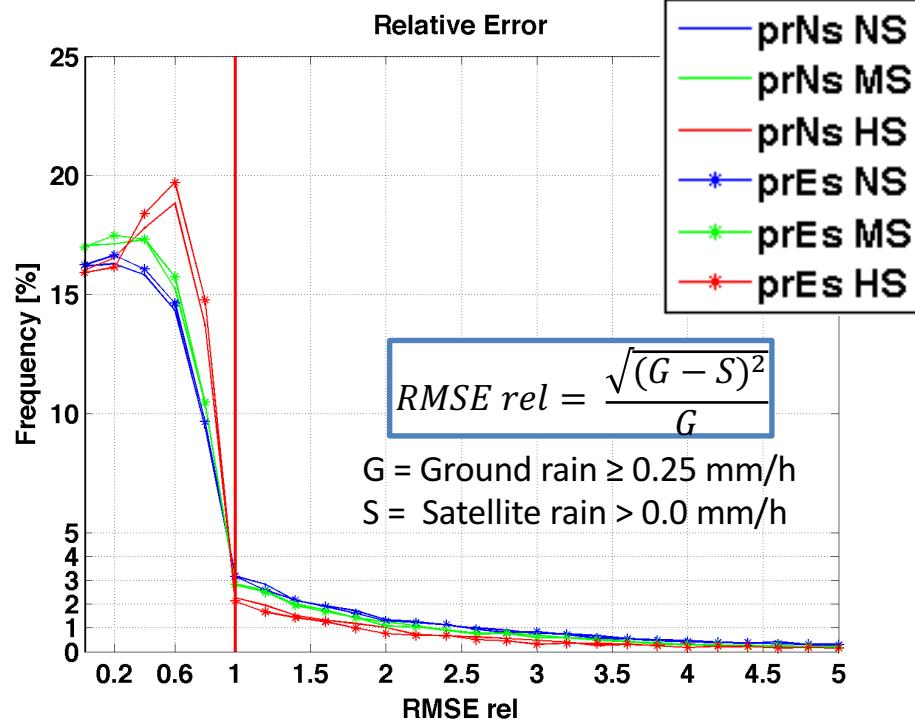
[www.protezionecivile.gov.it](http://www.protezionecivile.gov.it)



Generally RMSErel is between 40-60% related to RR between 1-2 mm/h



$\text{RMSE}_{\text{rel}} = 0 \rightarrow \text{PERFECT SCORE}$	(RR 2 mm/h)	(17.8%)
$0 < \text{RMSE}_{\text{rel}} < 1 \rightarrow \text{over/under-estimates}$		(67.6%)
$\text{RMSE}_{\text{rel}} = 1 \rightarrow \text{Sat} = 2 * \text{Ground} \text{ (or Sat} << \text{Ground)}$		( 2.0%)
$\text{RMSE}_{\text{rel}} > 1 \rightarrow \text{Sat} > 2 * \text{Ground}$	(RR>3mm/h)	(12.6%)




---

$RMSE_{\text{rel}} = 0 \rightarrow \text{PERFECT SCORE}$	(16.4%)
$0 < RMSE_{\text{rel}} < 1 \rightarrow \text{over/under-estimates}$	(61.7%)
$RMSE_{\text{rel}} = 1 \rightarrow \text{Sat} = 2 * \text{Ground} (\text{or Sat} \ll \text{Ground})$	( 2.7%)
$RMSE_{\text{rel}} > 1 \rightarrow \text{Sat} > 2 * \text{Ground}$	(19.2%)

---

# Statistical scores

Results: Seasonal scores

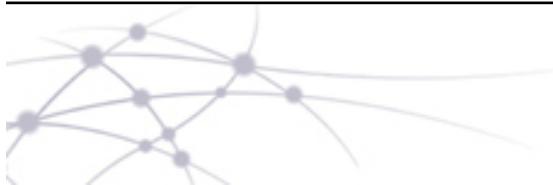
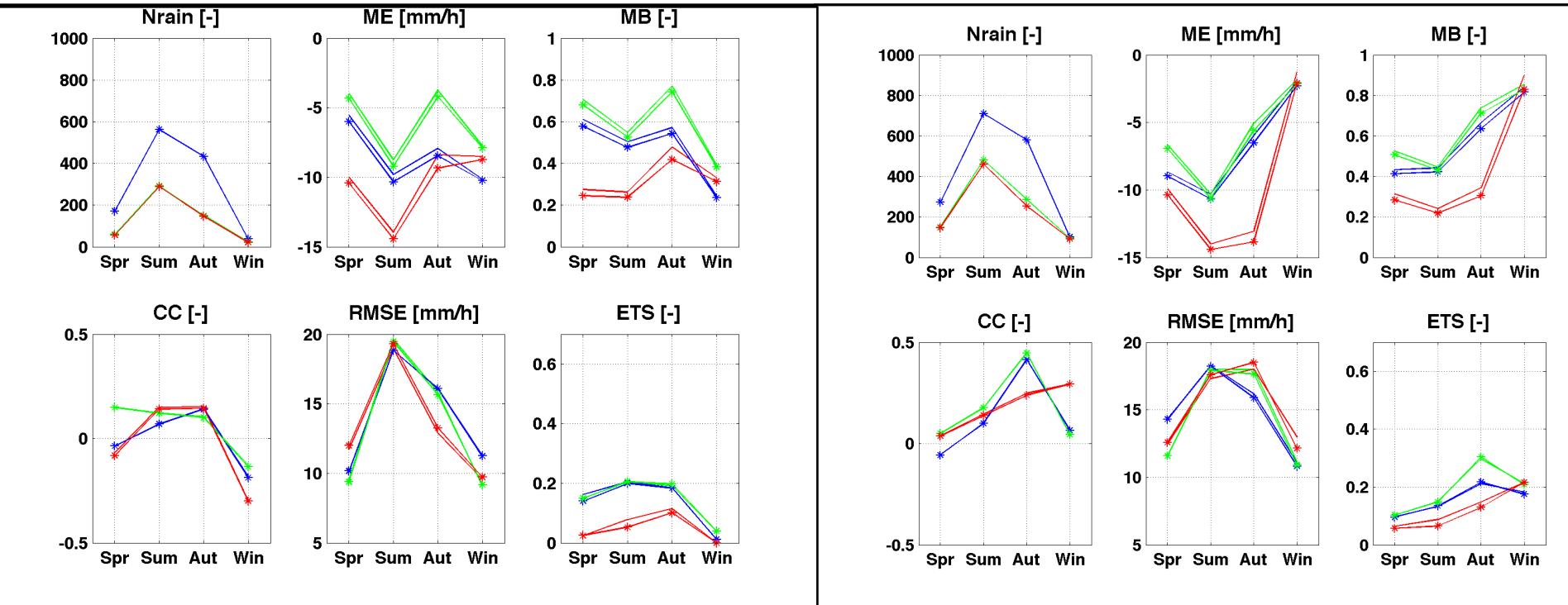
[www.protezionecivile.it](http://www.protezionecivile.it)

- prNs NS
- prNs MS
- prNs HS
- \* prEs NS
- \* prEs MS
- \* prEs HS

Rain  $\geq 10 \text{ mm/h}$

RADAR

RAIN GAUGE



# RADAR

Total statistical scores  
(27 months)  
DPR VS RD

mar-14		NS			MS			HS		
mag-16		>=0.25	>=1	>=10	>=0.25	>=1	>=10	>=0.25	>=1	>=10
prNs	'Nrain'	60056	24427	1205	30932	12948	526	28827	12088	511
	'ME'	-0,38	-0,76	-8,53	-0,36	-0,75	-6,75	-0,75	-1,47	-11,71
	'MB'	0,78	0,78	0,53	0,79	0,78	0,62	0,56	0,57	0,32
	'CC'	0,48	0,41	0,11	0,47	0,40	0,12	0,45	0,36	0,12
	'RMSE'	3,37	5,08	16,62	3,43	5,10	17,31	2,93	4,42	16,41
prEs	'Nrain'	60056	24427	1205	30932	12948	526	28827	12088	511
	'ME'	-0,43	-0,87	-9,03	-0,41	-0,84	-7,17	-0,83	-1,63	-12,30
	'MB'	0,75	0,75	0,51	0,76	0,75	0,59	0,52	0,52	0,29
	'CC'	0,48	0,41	0,10	0,47	0,40	0,12	0,45	0,35	0,11
	'RMSE'	3,31	5,00	16,65	3,36	5,00	17,15	2,91	4,41	16,73

mar-14		NS			MS			HS		
mag-16		>=0.25	>=1	>=10	>=0.25	>=1	>=10	>=0.25	>=1	>=10
prNs	POD	0,50	0,55	0,34	0,55	0,56	0,34	0,51	0,50	0,11
	FAR	0,17	0,30	0,72	0,18	0,29	0,71	0,16	0,20	0,79
	CSI	0,46	0,45	0,18	0,49	0,45	0,18	0,47	0,44	0,08
	ETS	0,44	0,44	0,18	0,47	0,44	0,18	0,45	0,44	0,08
prEs	POD	0,50	0,54	0,31	0,55	0,55	0,33	0,50	0,48	0,08
	FAR	0,17	0,29	0,71	0,18	0,29	0,70	0,15	0,19	0,81
	CSI	0,45	0,44	0,18	0,49	0,45	0,19	0,46	0,43	0,06
	ETS	0,43	0,43	0,18	0,47	0,44	0,19	0,44	0,42	0,06



# GRISO

Total statistical scores  
(27 months)  
DPR VS GRISO

mar-14		NS			MS			HS		
mag-16		>=0.25	>=1	>=10	>=0.25	>=1	>=10	>=0.25	>=1	>=10
prNs	'Nrain'	100792	38967	1666	52242	20607	1010	49095	19001	952
	'ME'	-0.46	-0.98	-8.02	-0.50	-1.03	-7.49	-0.83	-1.77	-11.91
	'MB'	0.70	0.69	0.54	0.69	0.69	0.57	0.49	0.48	0.33
	'CC'	0.47	0.42	0.22	0.52	0.47	0.29	0.44	0.38	0.11
	'RMSE'	3.15	4.82	16.57	3.25	5.00	16.66	2.98	4.68	16.48
prEs	'Nrain'	100792	38967	1666	52242	20607	1010	49095	19001	952
	'ME'	-0.51	-1.07	-8.43	-0.54	-1.11	-7.86	-0.90	-1.91	-12.46
	'MB'	0.67	0.66	0.51	0.67	0.67	0.55	0.45	0.44	0.29
	'CC'	0.47	0.42	0.22	0.52	0.47	0.29	0.44	0.37	0.10
	'RMSE'	3.07	4.72	16.44	3.19	4.91	16.49	2.97	4.67	16.72

mar-14		NS			MS			HS		
mag-16		>=0.25	>=1	>=10	>=0.25	>=1	>=10	>=0.25	>=1	>=10
prNs	POD	0.36	0.41	0.30	0.40	0.45	0.31	0.37	0.38	0.15
	FAR	0.36	0.43	0.76	0.35	0.40	0.69	0.32	0.36	0.68
	CSI	0.30	0.31	0.15	0.33	0.34	0.18	0.32	0.31	0.11
	ETS	0.28	0.31	0.15	0.31	0.34	0.18	0.30	0.31	0.11
prEs	POD	0.35	0.41	0.29	0.40	0.44	0.30	0.36	0.36	0.12
	FAR	0.36	0.43	0.75	0.35	0.40	0.67	0.31	0.35	0.68
	CSI	0.30	0.31	0.16	0.33	0.34	0.18	0.31	0.31	0.10
	ETS	0.28	0.31	0.16	0.31	0.34	0.18	0.30	0.30	0.10

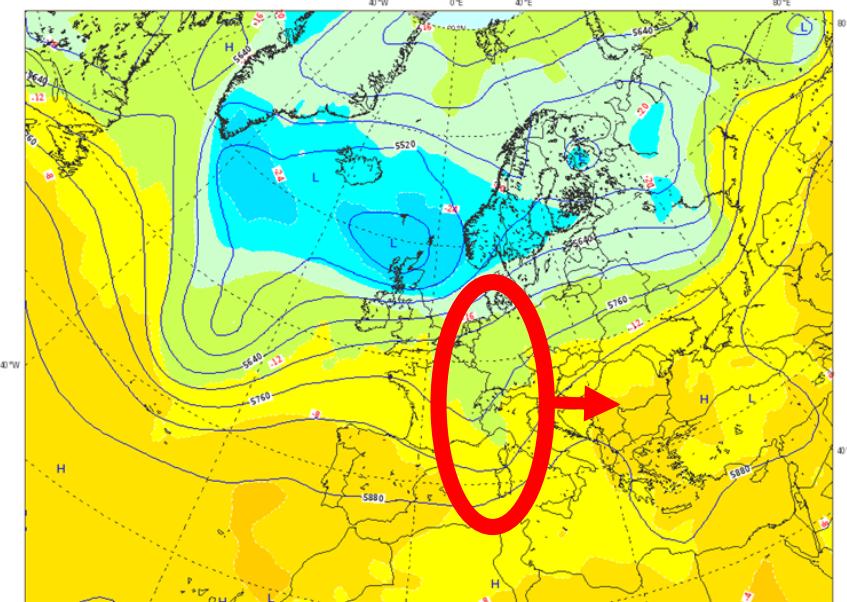


# Event of 1<sup>st</sup> August 2015 18:50 UTC

## Strong thunderstorms in Northern Italy



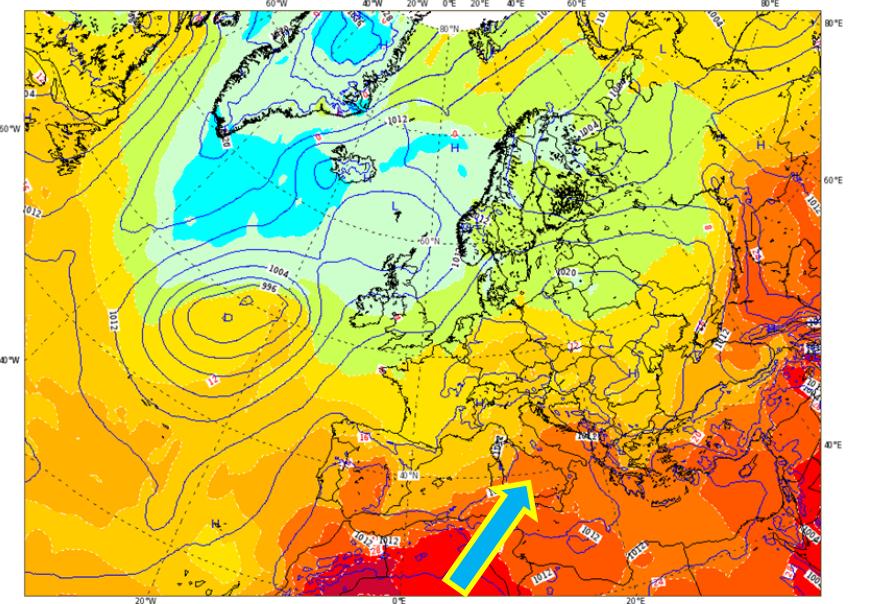
ECMWF 01 August 2015 12UTC Forecast T+6 VT: Saturday 01 August 2015 18UTC  
EUROATLANTIC - Geopotential at 500 hPa + Temperature at 500 hPa



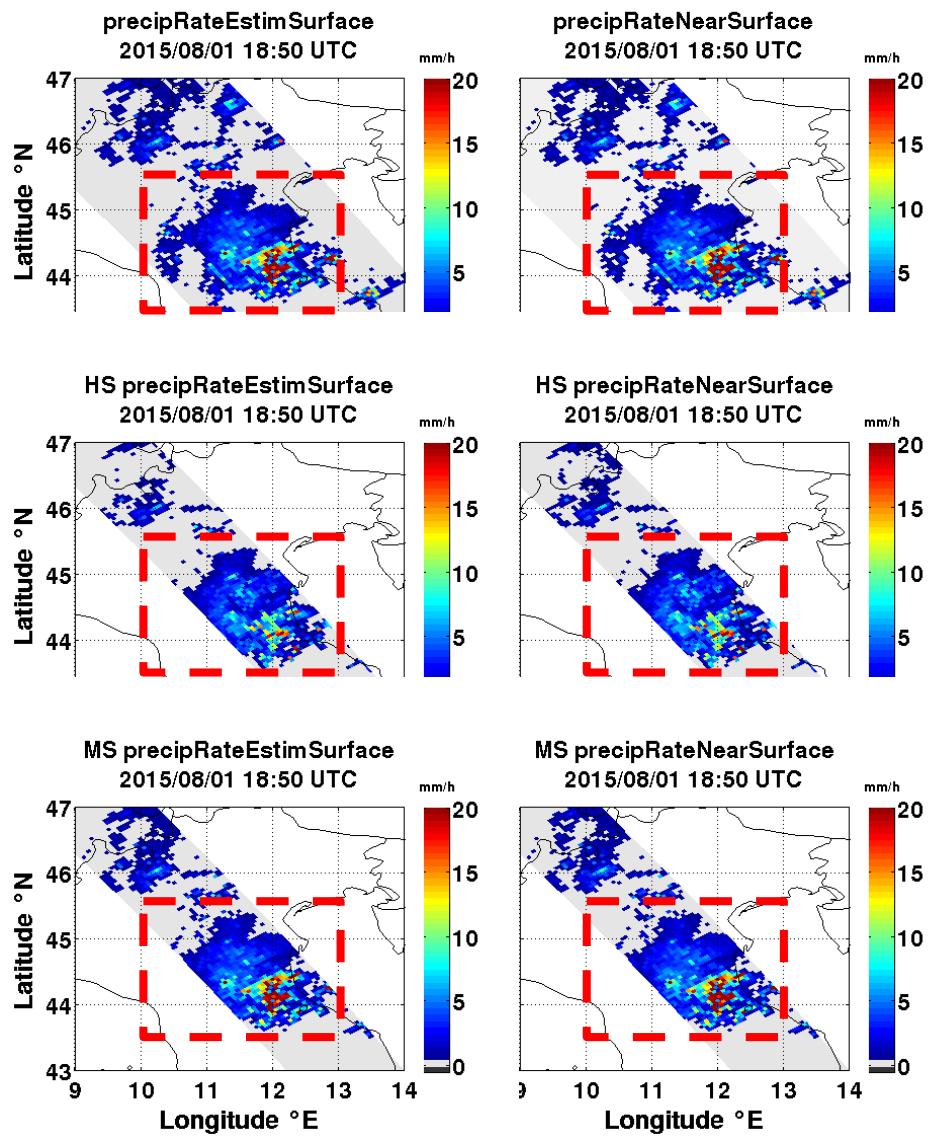
In low layers the pressure (MSLP) over the Mediterranean is high and leveled, very warm air (at 850 hPa) from north Africa reaches the central part of Italy. The shallow cold front brings only a slight decrease of temperatures.



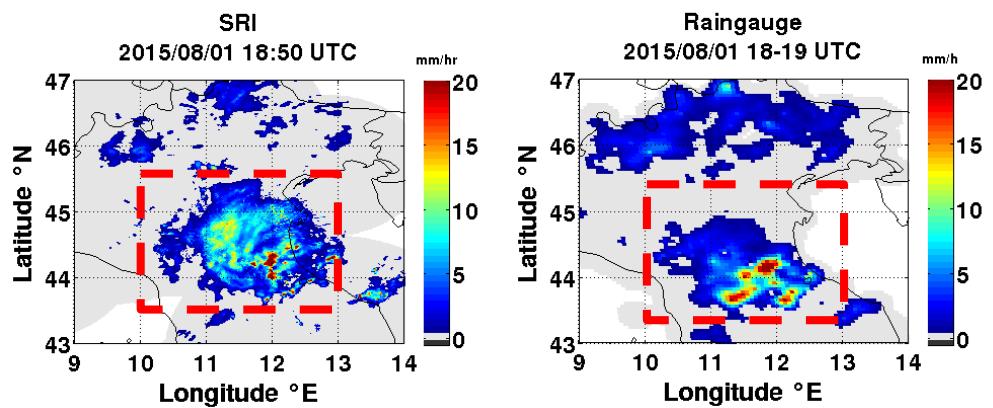
ECMWF 01 August 2015 12UTC Forecast T+6 VT: Saturday 01 August 2015 18UTC  
EUROATLANTIC - MSLP (hPa) + Temperature at 850 hPa (°C)



An Atlantic perturbation, a week and fast moving short wave trough, is reaching the western Mediterranean and is moving towards Italy. The trough reaches northern Italy, with a moderate cold air advection in high atmospheric layers.



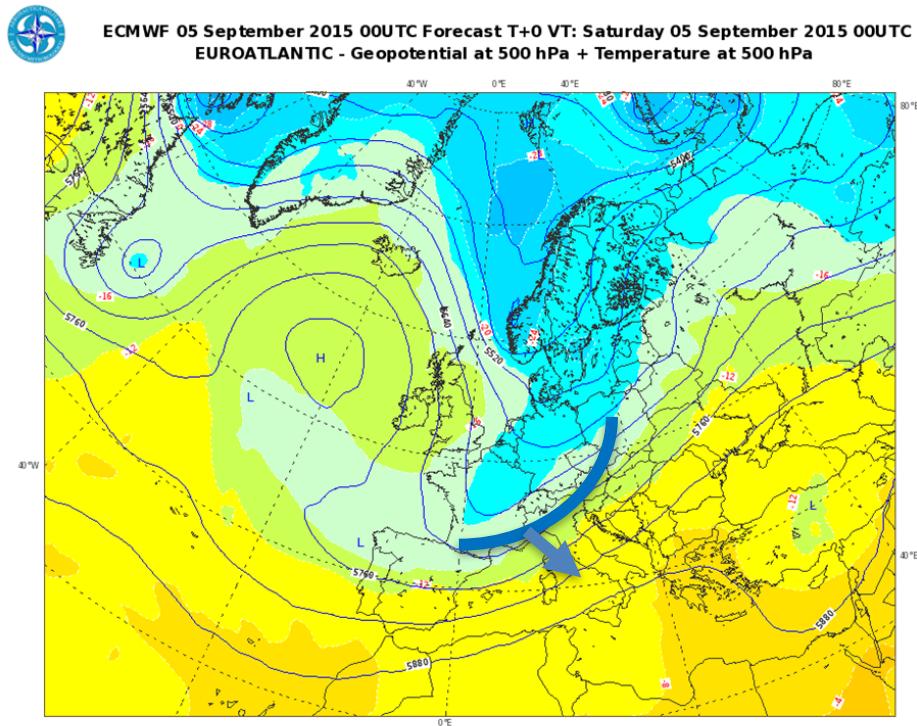
2015/08/01 18:50 UTC  
Emilia Romagna



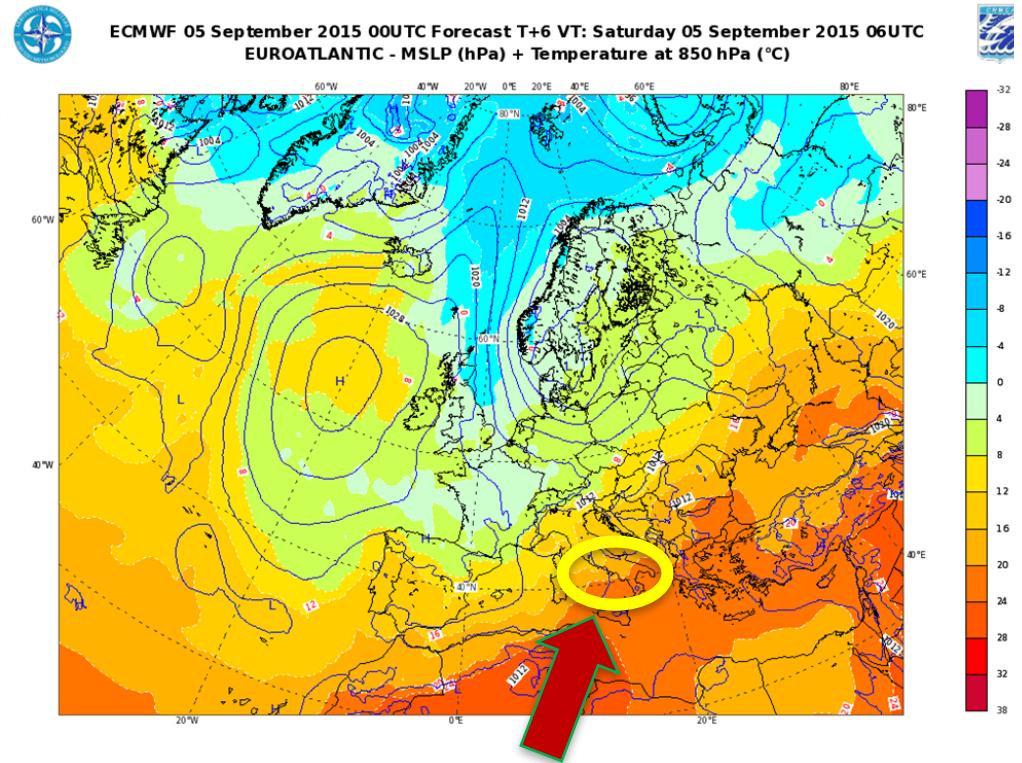
DPR vs	RADAR	GRISO
ME	-1,61	-0,48
STD	5,46	7,05
MB	0,71	0,91
CC	0,46	0,46
RMSE	5,81	7,11
ETS	0,41	0,42

# Event of 5<sup>th</sup> September 2015 8:50 UTC Strong thunderstorms in Gulf of Naples

A vast low pressure system, a rather stationary long wave trough, is centered over Scandinavia and extends over large parts of Europe. A south-westerly flow is affecting the western and central Mediterranean. The cold front reaches central Europe.



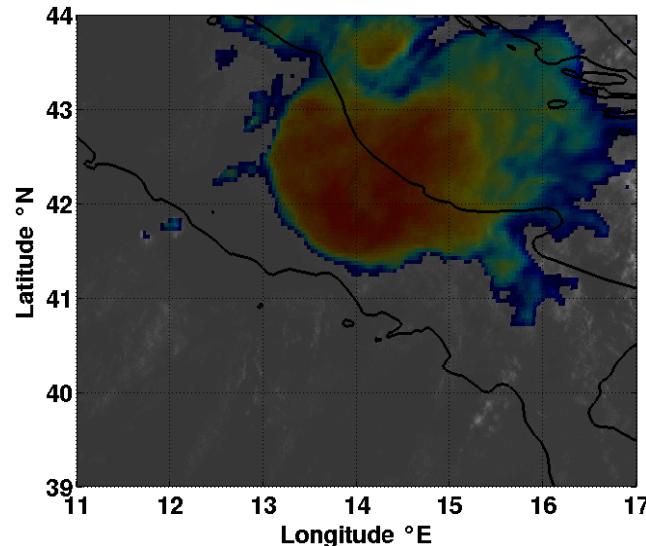
The pressure (MSLP) over the Mediterranean is rather high and leveled. In low layers (850 hPa) southerly winds are advecting very warm air from north-Africa towards southern Italy. Cold air masses from the north-west reaches the Tyrrhenian sea.



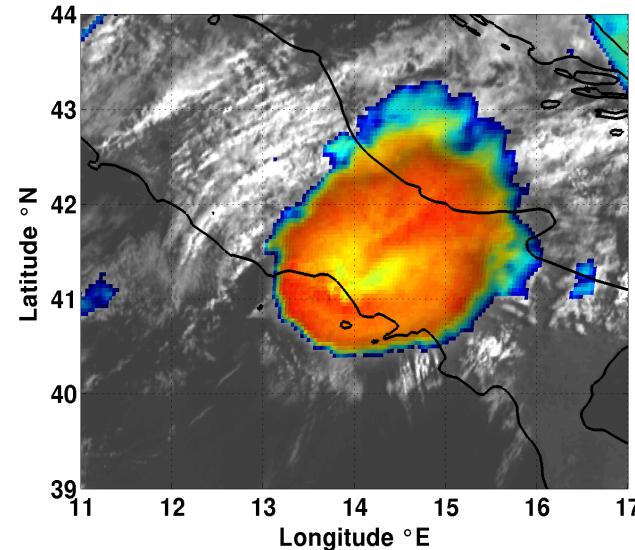


## MSG RSS HRV + IR 10.8

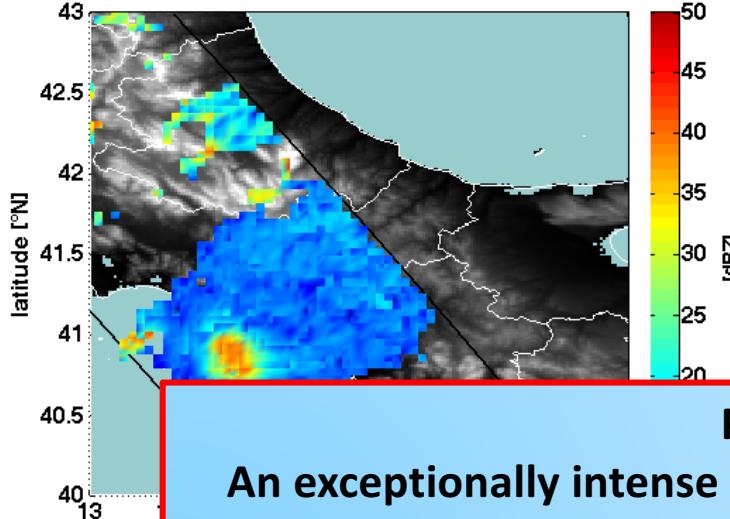
0502 UTC



0847 UTC



2A-Ku Z Factor Measurec

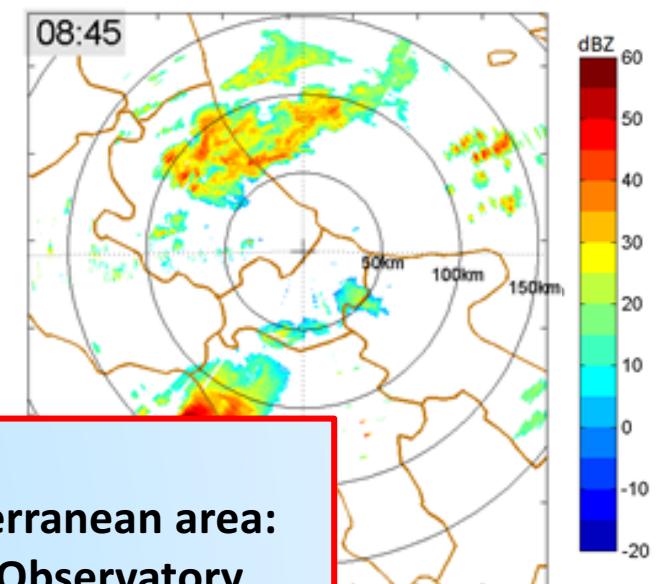


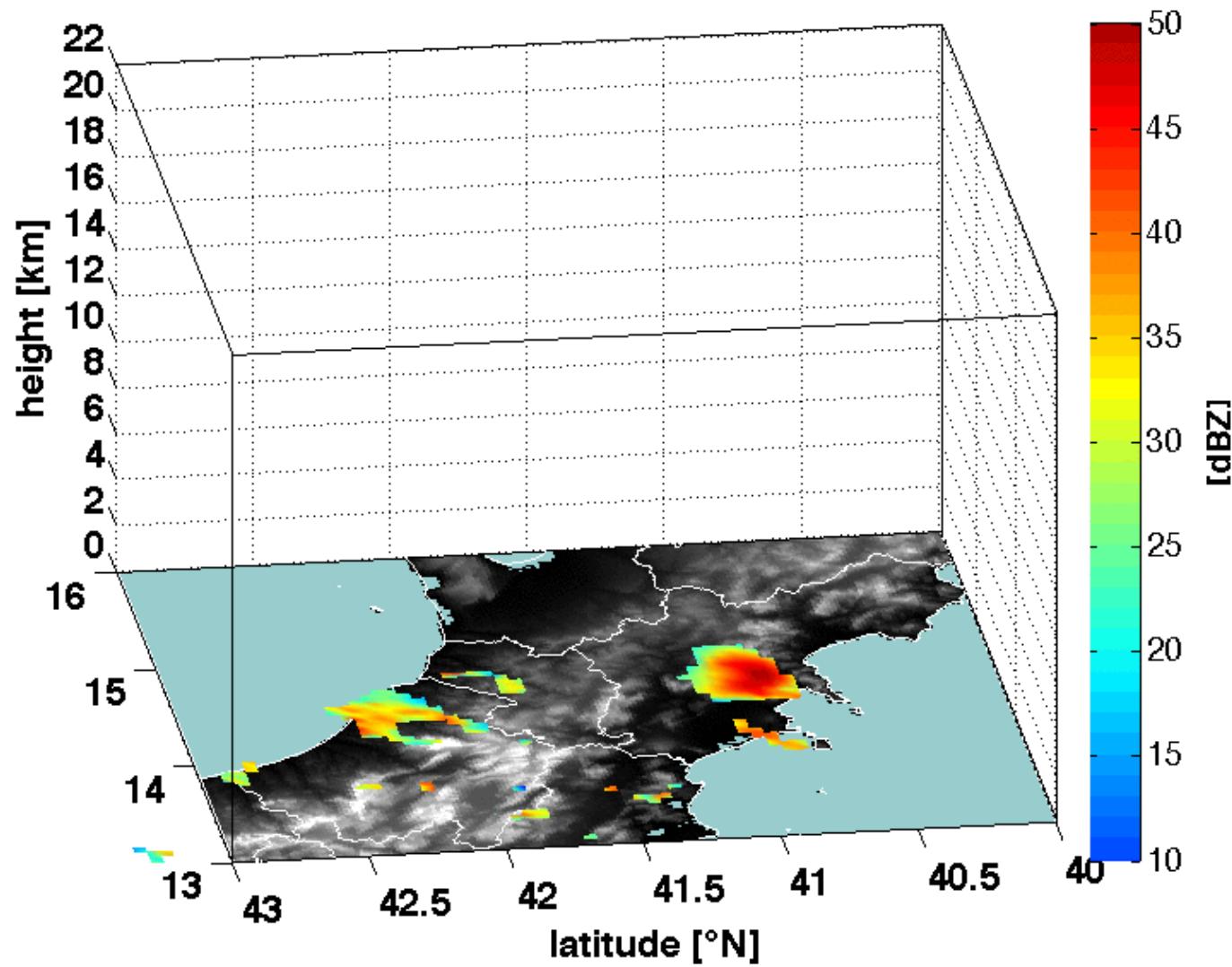
DPR vs	RADAR
ME	-2,58
STD	17,18
MB	0,66
CC	0,38
RMSE	5,72

### POSTER N° 225:

An exceptionally intense hailstorm over the Mediterranean area:  
Observational analysis and role of the GPM Core Observatory

G. Panegrossi et al.





# Summary

- Validation has been performed for **Product Level 2A DPR V04 PrecipRateESurface, PrecipRateNearSurface: NS, MS and HS** using the Italian rain gauge and radar data **2014/03 – 2016/05 (27 months)**
- The validation results obtained using radar data are very similar to the results obtained using rain gauges → good reference data set.
- The analysed products show:
  1. The **NearSurface** and **EstimatedSurface** have really similar performances;
  2. About **NS, MS and HS**:
    - Quite good capability to catch precipitation pattern: rain/no rain classification 99% and ETS eq. 0.4;
    - General underestimation (ME -0.4 mm/h and CC 0.5) in particular by HS for heavy precipitation (ME -12 mm/h)
    - Generally RMSErel is between 40-60% related to RR between 1-2 mm/h. Only for 13% of samples there is a big over-estimation >2\*Ground (RR>3mm/h)
    - Seasonal component has been observed: the best results are obtained during summer and autumn in terms of ME, MB and ETS by the MS;
    - The seasonal results are confirmed by the overall statics: the statical scores evaluated with rain gauge and radar data for the **MS** are the best in term of continuos statistics (ME, RMSE, CC) and dichotomy statistics (POD, FAR, ETS) for all regimes of precipitation(light, moderate and heavy precipitation).



# Next steps

- Analyse the impact of the orography on the statistical scores;
- Deliver the validation code the H-SAF PPVG for an extensive validation of DPR over Europe;
- Provide case study analysis of the last severe storm occurred in Europe;
- Validate GMI and IMARGE products in H-SAF area.

Thank you



# Statistical indexes

$$ME = \frac{1}{N} \sum_{k=1}^N (sat_k - obs_k)$$

$$MB = \frac{\frac{1}{N} \sum_{k=1}^N sat_k}{\frac{1}{N} \sum_{k=1}^N obs_k}$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{k=1}^N (sat_k - obs_k)^2}$$

$$POD = \frac{hits}{hits + misses} = \frac{hits}{observed yes}$$

$$FAR = \frac{false alarms}{hits + false alarms} = \frac{false alarms}{forecast yes}$$

$$CSI = \frac{hits}{hits + misses + false alarm}$$

Event forecast	Event observed		
	Yes	No	Marginal total
Yes	a	b	a + b
No	c	d	c + d
Marginal total	a + c	b + d	a + b + c + d = n

**ETS** = (a - a<sub>r</sub>) / (a + b + c - a<sub>r</sub>), where a<sub>r</sub> = (a + b) (a + c) / n

ETS = (hits - hits expected by chance) / (hits + false alarms + misses - hits expected by chance)

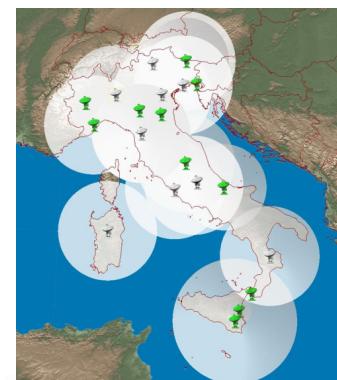
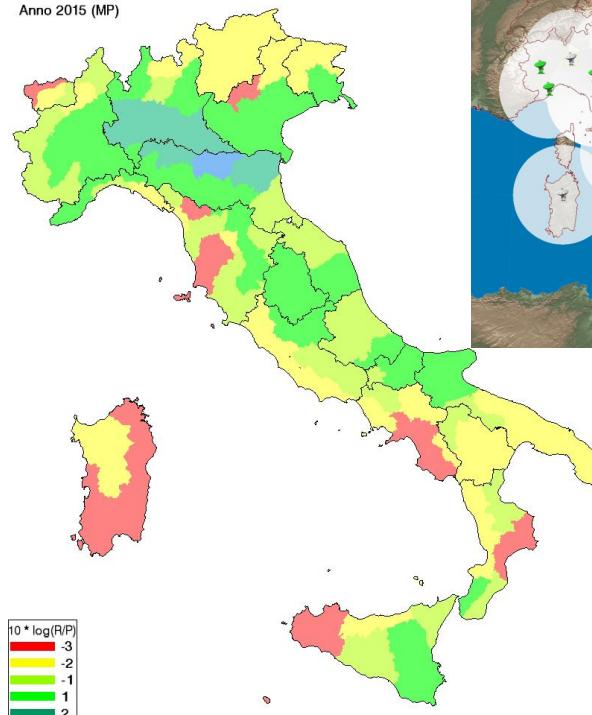
a<sub>r</sub> = (total forecasts of the event) \* (total observations of the event) / (sample size)



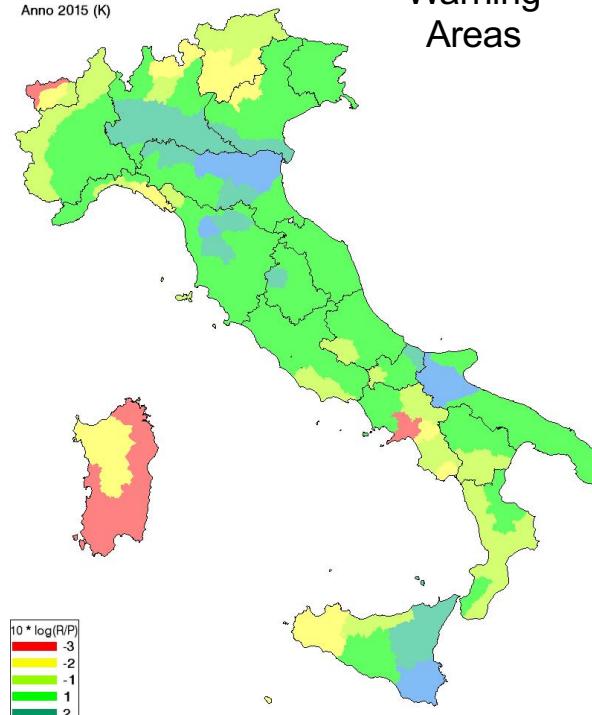
## Performance Analysis: spatial distribution of Ratio Bias (aggregated per warning area)

133  
Warning  
Areas

Anno 2015 (MP)



Anno 2015 (K)

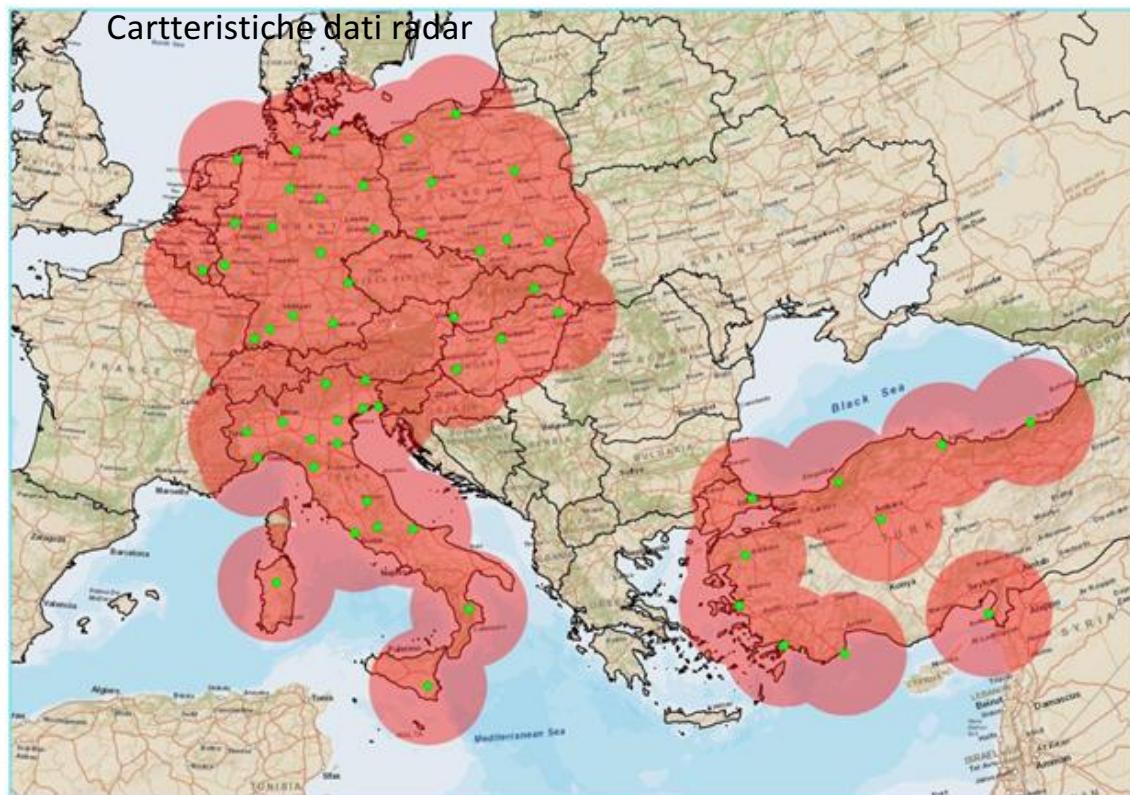


Single-polarization  
rainfall algorithm R(Z)

Polarimetric rainfall algorithm R(Z, K<sub>DP</sub>)  
(Vulpiani et al., 2015)

# Precipitation Product Validation Group

The *Precipitation Product Validation Group (PPVG)* is composed of experts from the National Meteorological and Hydrological Institutes of **8 European countries** under the coordination of the Italian Civil Protection Department (DPC). The PPVG uses both **rain gauge** and **radar** data for validation of precipitation products.



Country (Acronyms)	Institutes
Belgium (BE)	IRM
Bulgaria (BG)	NIMH
Germany (DE)	BfG
Hungary (HU)	OMSZ
Italy (IT-DPC, IT-UNIFE)	DPC, UniFe
Poland (PL)	IMWM
Slovakia (SK)	SHMU
Turkey (TU)	ITU, METU, TSMS

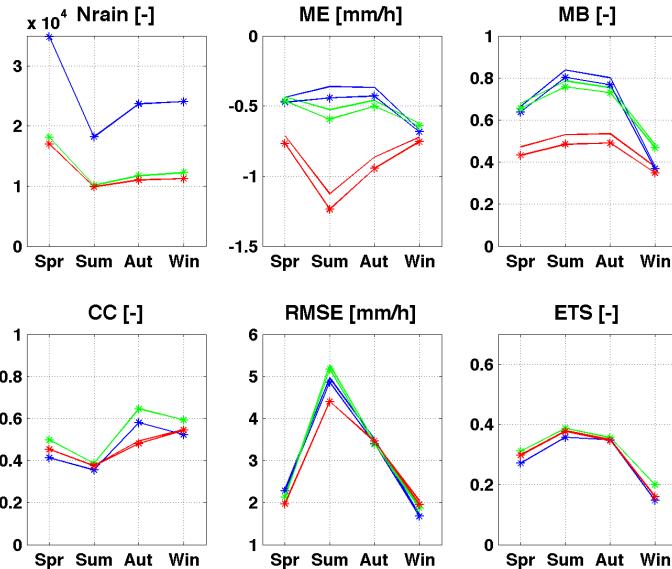
  

Country	Total number of gauges *	Average minimum distance (km)
Belgium	89**	11.2
Germany	1300	17
Italy	2600	9.5
Poland	330-475	13.3
Turkey	193***	27

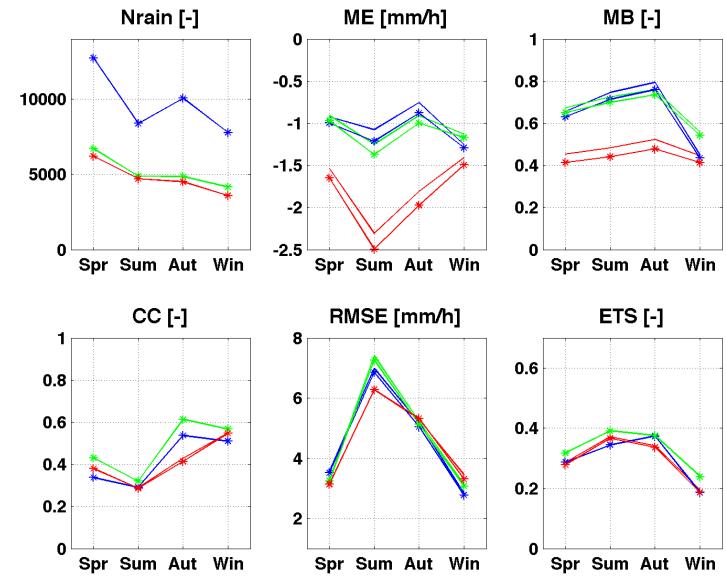
\* the number of rain gauges could vary from day to day due to operational efficiency within a maximum range of 10-15%.  
\*\* only in the Wallonia Region  
\*\*\* only covering the western part of Anatolia

# GRISO

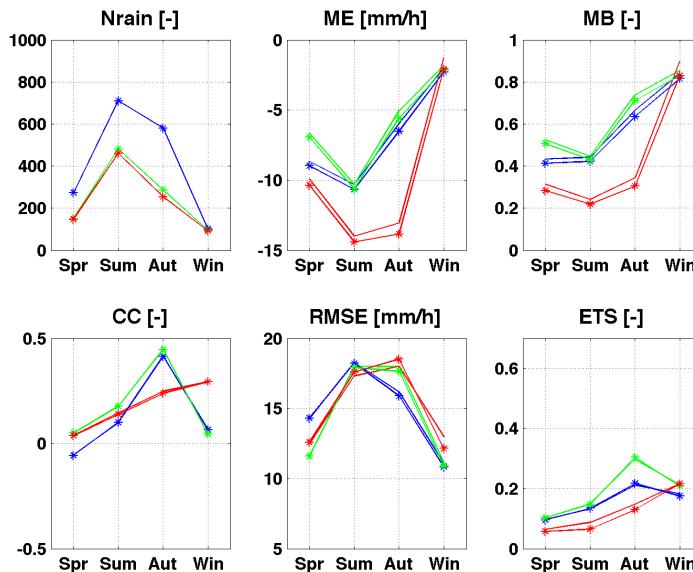
0.25 mm/h



1.00 mm/h



10 mm/h



# RADAR

**Rain  $\geq 10 \text{ mm/h}$**

